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Review

Personalized Selection of Central Venous Access Devices: Patient-Specific Risk Assessment and Emerging Technologies—A Narrative Review

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Abstract

Central venous access devices (CVADs) support treatments that require reliable central administration, yet choosing between available systems involves more than procedural feasibility. This narrative review examines how infusion requirements, vascular anatomy, thrombotic and infectious risks, preservation of future venous access, maintenance demands, and patient priorities influence device choice. Non-tunneled and tunneled central catheters, peripherally inserted central catheters (PICCs), totally implantable venous access devices (TIVADs), upper-arm ports, PICC-port systems, and femorally inserted central catheters are considered. In selected oncology populations, comparative studies favor implanted ports over PICCs for several device-related complications; nevertheless, these findings do not establish a universally preferred device. Catheter caliber, vessel selection, insertion and tip-location techniques, and maintenance practices further influence outcomes. Evidence for upper-arm implantable systems is growing, whereas advanced biomaterials, predictive models, and sensor-enabled monitoring require further clinical validation. Formal patient-reported outcome measures should be distinguished from individual preferences elicited during consultation. The review synthesizes current evidence and clinical guidance to support risk-informed, shared vascular-access decisions while identifying limitations in comparative research and emerging technologies.

Keywords: central venous access devices; vascular access; peripherally inserted central catheter; totally implantable venous access device; PICC port; device selection; risk stratification; personalized medicine

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1. Introduction

Central venous access devices (CVADs) provide reliable access for therapies that cannot be delivered safely or effectively through peripheral veins, including systemic anti-

cancer treatment, parenteral nutrition, prolonged antimicrobial administration, and selected critical-care infusions [1]. As care moves between hospitals, outpatient services, and patients' homes, vascular access must remain suitable throughout a course of treatment that may change in intensity or duration [1,2]. Choosing a catheter therefore has consequences beyond successful insertion: it can affect continuity of therapy, complications, healthcare utilization, and daily activities [2–4].

Several developments underpin current practice. Early experiments in central catheterization and the Seldinger guidewire technique established essential procedural principles [5,6]. Tunneled catheters and implantable ports subsequently enabled prolonged or repeated treatment without relying on repeated peripheral cannulation [7,8]. Ultrasound-guided venipuncture, intraprocedural tip-location methods, and refinements in device design have further improved insertion techniques [9–11]. The main options now include non-tunneled centrally inserted catheters, tunneled external catheters, PICCs, and totally implantable venous access devices (TIVADs) [12]. Upper-arm ports and PICC-port systems extend this range, although their comparative evidence is less established [13–15].

Greater device diversity has not produced a simple hierarchy of suitability. Anticipated dwell time matters, but it must be considered alongside whether treatment is continuous or intermittent, the properties of the infusate, required flow rates, and the number of lumens [2–4,16,17]. A usable venous pathway must also be identified: vessel caliber and patency, previous catheterization, thrombosis, infection risk, and technical constraints can exclude an otherwise attractive option [3,4,16]. In advanced chronic kidney disease, protecting upper-extremity veins for possible future dialysis access may take precedence over insertion convenience [4]. Practical factors—including dressing care, visibility, mobility, body image, and the patient's capacity to manage an external device—also influence whether a particular system is acceptable [3,17].

An unsuitable device may lead to preventable complications or interrupted therapy. Bloodstream infection, thrombosis, occlusion, malposition, and mechanical failure can necessitate removal or replacement and may jeopardize subsequent venous access [18–20]. These outcomes reflect not only catheter type but also patient characteristics, lumen count, catheter diameter, insertion route, operator technique, and maintenance practices [18–20]. Because study populations, indications, and follow-up periods differ, complication rates cannot always be extrapolated from one clinical setting to another, particularly when comparing PICCs, tunneled catheters, and implantable ports [21,22].

The oncology literature illustrates this complexity. In the randomized CAVA trial and subsequent comparative evidence, implanted ports showed advantages over some external devices for several complications in appropriately selected patients [21,22]. Such findings support their consideration but do not override treatment urgency, anatomical constraints, comorbidities, or the intended pattern of access. Patient experiences—such as discomfort, restrictions on daily activities, and the work involved in device care—provide additional information beyond infection or thrombosis rates [23]. Meanwhile, expanding use of PICC-port systems raises questions about their place relative to established alternatives, particularly where direct comparative trials remain sparse [13–15,23].

This narrative review therefore focuses on the clinical reasoning behind CVAD choice rather than proposing a fixed device ranking. We examine how treatment requirements, available venous anatomy, complication risks, and patients' priorities interact; compare the principal established devices; and critically appraise newer configurations and technologies. Particular attention is given to the strength and applicability of comparative findings, the preservation of future vascular access, and the distinction between promising innovations and interventions supported by clinical outcome data. Our objective is to provide a practical

evidence-informed basis for shared decision-making and to identify questions that require more rigorous investigation.

2. Review Methodology

This narrative review was developed through iterative, topic-oriented literature identification rather than a prespecified systematic-review protocol. Sources consulted included PubMed/MEDLINE, PubMed Central, peer-reviewed journal websites, and reference lists of relevant publications; Scopus and Embase were not searched. The literature identification began in August 2026, and the bibliography was updated through November 2026 during manuscript revision. No formal publication-date filter or prospectively established systematic search cutoff was used; the precise dates of individual database searches were not logged. Representative search concepts included 'central venous access device', 'PICC', 'implantable port', 'PICC-port', 'femorally inserted central catheter', 'catheter-related thrombosis', 'catheter-related bloodstream infection', 'catheter-to-vein ratio', 'chronic kidney disease', 'venous preservation', 'patient-reported outcomes', and combinations of device names with 'complications', 'selection', or 'guidelines'. These terms describe topics used in the literature identification, not a retrospectively reconstructed, fully reproducible Boolean strategy. Publications were prioritized for direct relevance to patient-specific device selection, study design, population applicability, outcome definition, and clinical relevance. Guidance documents and expert consensus were used to contextualize appropriateness, whereas randomized trials and systematic reviews were assigned greater interpretive weight for comparative clinical outcomes. Observational reports were considered when more robust comparative evidence was unavailable, especially for newer device configurations.

Evidence was synthesized qualitatively across treatment requirements, vascular anatomy, device characteristics, thrombosis and infection risk, venous preservation, maintenance, and patient experience. Publications outside these themes, studies judged insufficiently relevant or reliable for a specific claim, and sources with poorly applicable populations or endpoints were not prioritized. Apparent conflicts were evaluated in relation to study design, clinical setting, patient population, outcome definitions, follow-up, and precision; discrepant findings were reported without imposing an unsupported overall device ranking. No prospective protocol, systematic screening log, formal risk-of-bias assessment, or meta-analysis was undertaken. This is therefore a selective clinical narrative synthesis, not an exhaustive systematic review. The methodological approach is consistent with published recommendations for narrative literature reviews, particularly regarding transparency in literature identification, evidence selection, and qualitative synthesis [24].

3. Classification and Functional Characteristics of Central Venous Access Devices

Central venous access devices (CVADs) comprise catheters whose tips terminate in the central venous circulation, irrespective of the entry site. Conventional classification distinguishes non-tunneled centrally inserted catheters, tunneled central venous catheters, PICCs, and totally implantable venous access devices. In practice, however, configurations overlap: a PICC may be tunneled, and a port may be introduced through a thoracic, upper-arm, or occasionally femoral vein [25].

A multidimensional terminology can describe this diversity more precisely. The GloVANet–WoCoVA NAVIGATE position statement classifies devices by insertion route (central, peripheral, or femoral), tunneling and cuff status, external or implanted access component, lumen count, material, tip configuration, and function [25]. This approach distinguishes centrally inserted central catheters (CICCs), PICCs, femorally inserted central catheters (FICCs), tunneled systems, and ports without forcing clinically different

devices into rigid categories. These features help explain differences in insertion complexity, flow capacity, expected use, patient experience, and infectious, thrombotic, or mechanical complications [1–3,12].

The prescribed infusate, need for central administration, access frequency, and expected treatment course establish the initial requirements. Final choice should also account for ultrasound-assessed anatomy, catheter-to-vein relationship, previous vascular access, infection and thrombosis risks, comorbidities, preservation of future venous options, procedural expertise, and patient preferences [2,4,12,16,17,26,27]. Figure 1 summarizes these interacting domains as an author-proposed framework rather than a validated algorithm.

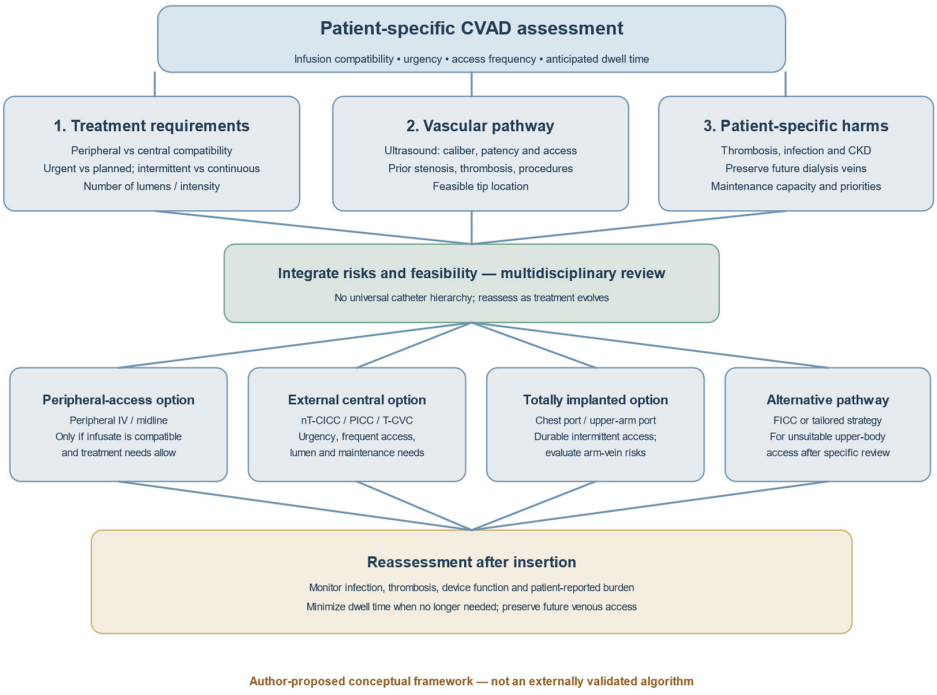


Figure 1. Author-proposed, risk-informed framework for central venous access device selection. Treatment pattern, infusion compatibility, and urgency are evaluated alongside ultrasound-assessed vascular anatomy, thrombotic and infectious risks, preservation of veins for future dialysis access, and patient priorities. The schematic outlines decision domains and possible access strategies; it is not an externally validated or prescriptive algorithm. CKD, chronic kidney disease; CICC, centrally inserted central catheter; nT-CICC, non-tunneled centrally inserted central catheter; CVAD, central venous access device; FICC, femorally inserted central catheter; PICC, peripherally inserted central catheter; T-CVC, tunneled central venous catheter. Blue and blue-gray boxes represent patient-specific assessment domains and potential vascular access options; the green box indicates multidisciplinary integration of risks and feasibility; and the pale-yellow box denotes post-insertion reassessment and monitoring. Colors are used for visual organization and do not indicate risk severity or a hierarchy of device preference. The figure was generated using ChatGPT (OpenAI, GPT-6.2) based on the authors' conceptual framework and was reviewed and approved by the authors.

3.1. Non-Tunneled Centrally Inserted Central Catheters

Non-tunneled centrally inserted central catheters (nT-CICCs) are placed through cervical or thoracic central veins, commonly the internal jugular or axillary/subclavian veins, with the tip generally positioned in the lower superior vena cava or at the cavoatrial junction [25,28]. Available in single- and multi-lumen configurations, they provide prompt central access for vasoactive medications, incompatible infusates, simultaneous treatments, resuscitation, and hemodynamic monitoring in acute or critical care [28,29]. Large-bore non-tunneled catheters may also serve temporary hemodialysis or extracorporeal therapies,

but their diameter, flow characteristics, tip design, and complications differ substantially from standard infusion catheters [30].

Insertion-site selection requires balancing infectious, thrombotic, and mechanical hazards. In the randomized 3SITES trial, subclavian catheterization reduced a composite of catheter-related bloodstream infection and symptomatic deep-vein thrombosis compared with jugular or femoral access but increased mechanical complications, notably pneumothorax [29]. Choice of route must therefore take account of vascular anatomy, coagulation status, respiratory reserve, prior cannulation, suspected obstruction, and operator expertise. Real-time ultrasound guidance improves procedural success and reduces inadvertent arterial puncture and other insertion-related complications [28,31]. Femoral placement remains an option in emergencies or when thoracic access is unsuitable; under current terminology, this device is classified as a FICC rather than a CICC [25].

The principal advantage of nT-CICCs is immediate availability, not a fixed maximum duration of use. Indication, function, insertion-site condition, and signs of infection should be reviewed regularly. Aseptic placement, skin antisepsis, hub disinfection, and standardized maintenance bundles remain central to preventing catheter-related bloodstream infection [31,32]. Remove the line when it is no longer needed. When treatment is expected to continue, reassess whether a PICC, tunneled catheter, or implantable port would better fit the clinical situation.

3.2. Tunneled Central Venous Catheters

Tunneled central venous catheters (T-CVCs) pass through a subcutaneous tunnel before emerging at a skin exit site away from venous entry. Tunneling and cuffing are separate characteristics: these catheters may be cuffed or non-cuffed. Cuffed systems, including Hickman-, Broviac-, and Groshong-type devices, are used for sustained access and vary by lumen count, material, and tip configuration. Small-bore non-cuffed tunneled catheters provide an alternative when intermediate-duration therapy is anticipated, peripheral access is inadequate, or upper-extremity vein preservation is important [33,34]. Fully implanted ports are considered separately because they terminate in a subcutaneous reservoir rather than an external segment [25].

Indications include home parenteral nutrition, prolonged antimicrobial treatment, hematologic and oncologic therapy, repeated blood-product administration, and stem-cell transplantation [35]. A cuffed system may remain in place for months or longer while clinically needed and free of complications. Non-cuffed tunneled devices are often considered for intermediate use, especially in people with limited peripheral veins, previous PICC complications, or potential future dialysis needs [33,34]. Because they lack cuff-mediated tissue anchorage, securement and surveillance for migration are particularly important.

Placement usually involves internal jugular venous access followed by subcutaneous tunneling to a remote exit site. In cuffed devices, a polyester cuff gradually becomes incorporated into surrounding tissue, enhancing stability; the tunnel may also limit extraluminal microbial migration. Neither feature eliminates infection, so careful hub and exit-site care remains necessary. Non-cuffed devices require alternative securement. Ultrasound-guided venipuncture and fluoroscopy or another validated navigation method can help confirm the catheter course and tip position [30,36].

Tip location depends on the intended use. Infusion catheters generally terminate in the lower superior vena cava or at the cavoatrial junction. Tunneled hemodialysis catheters, in contrast, commonly extend to the mid-right atrium to support the blood flow needed for extracorporeal treatment and limit recirculation [30]. Their larger caliber, two-lumen design, and distinct complication profile warrant separate consideration. When future arteriovenous access is possible, the right internal jugular vein is commonly preferred for

dialysis catheterization; subclavian cannulation should generally be avoided because central venous stenosis could compromise later fistula or graft creation [30,36].

Important complications of T-CVCs include bloodstream, exit-site, and tunnel infections; thrombosis; intraluminal occlusion; fibrin-sheath formation; catheter fracture; migration; and accidental removal [34,36]. Outcomes depend on aseptic handling, suitable flushing and locking, securement, and timely investigation of device dysfunction. A tunneled external catheter may be useful when frequent or continuous access is required, whereas a fully implanted port may reduce external maintenance for intermittent therapy over several months. The distinction between cuffed and non-cuffed systems should be based on the intended treatment, vascular anatomy, likely duration, care setting, and patient capacity rather than a rigid dwell-time rule [30,33–36].

3.3. Peripherally Inserted Central Catheters

Peripherally inserted central catheters (PICCs) enter through an upper-extremity vein and advance to the central venous circulation. The basilic, brachial, and cephalic veins are potential access sites, although ultrasound findings should guide the final approach rather than a fixed vessel preference. PICCs are used for anticancer and hematologic treatment, intravenous antimicrobials, parenteral nutrition, and other therapies requiring reliable central administration. Neither ease of placement nor expected dwell time alone establishes suitability: infusion requirements, urgency, vessel anatomy, thrombosis and infection risk, underlying disease, possible future dialysis access, and patient circumstances all matter [1–3,16,17,25].

Ultrasound evaluation before PICC insertion is essential to identify a suitable vein. Vessel diameter, depth, patency, anatomical course, previous thrombosis, and surrounding neurovascular structures should be evaluated before catheter placement. Catheter caliber relative to vein size is particularly relevant because increasing venous occupancy may reduce local blood flow and contribute to catheter-related thrombosis. Sharp et al., in a multicenter cohort of 2438 PICC insertions, reported that a catheter-to-vein ratio greater than 45% was associated with an increased risk of symptomatic thrombosis, both in the overall cohort and among patients with malignancy, whereas the 33% cut-off was not significantly associated with thrombosis [26]. However, the study was unable to establish an optimal catheter-to-vein ratio using receiver operating characteristic analysis; these findings therefore support consideration of catheter-to-vein ratio as one component of an integrated thrombosis-risk assessment rather than reliance on a single universal threshold. Selection of the smallest catheter diameter and the minimum number of lumens required for the prescribed therapy remains an important modifiable component of thrombosis-risk mitigation [2,3,20,26].

A PICC can generally be inserted under local anesthesia with ultrasound guidance, without direct thoracic venipuncture or creation of a port pocket. Tip navigation may include intracavitary electrocardiography when clinically appropriate [9–11]. These features make PICCs useful when access is needed promptly, or a totally implanted system is unsuitable. Procedural convenience, however, should not be confused with the best long-term choice for an individual patient [2–4,17].

Venous preservation warrants particular attention in advanced kidney disease. Patients with advanced chronic kidney disease require particular caution before placement of an upper-extremity PICC because thrombosis or stenotic injury may compromise veins required for future arteriovenous access. Appropriateness guidance supports multidisciplinary assessment when cancer treatment requirements coexist with advanced chronic kidney disease, balancing the immediate need for vascular access against the preservation of veins that may be required for future dialysis access [4,30,33]. More broadly, previous upper-extremity thrombosis, central venous stenosis, previous vascular access, and anticipated

future access requirements should be incorporated into device selection before insertion rather than addressed only after complications develop.

PICCs are subject to thrombosis, bloodstream infection, occlusion, migration, dislodgement, and other dysfunction that may interrupt treatment or prompt removal [18–20]. In selected oncology populations, randomized and meta-analytic evidence favors implanted ports for several device-related outcomes, particularly thrombosis [21,22,37]. The RCT-based synthesis by Qiu et al. included six reports from five randomized trials (1127 participants) and found higher incidences of total complications, thrombosis, deep-vein thrombosis, implantation failure, unplanned removal, and local reactions with PICCs [37]. These findings apply to the endpoints and populations studied and should inform, rather than dictate, individualized device selection [4,17,21,22,37].

Living with an external PICC requires dressing and connector care and may complicate bathing or physical activity. Some patients nonetheless prefer to avoid implantation and favor straightforward removal after a finite course. The treatment schedule, ability to maintain the device, and personal preferences should be discussed alongside clinical risks [2,4,17].

3.4. Totally Implantable Venous Access Devices

Totally implantable venous access devices (TIVADs), or ports, connect a central catheter to a subcutaneous reservoir. They are often suitable for prolonged intermittent systemic anticancer or supportive treatment [1,2,12,15,25]. When not accessed, they have no external segment and require no continuous external dressing, although each infusion requires non-coring needle access.

TIVAD implantation requires venous access and creation of a subcutaneous pocket. Ultrasound-guided venipuncture and patient-specific assessment of the access route are preferred to a fixed choice of vein [3,9,12]. Internal jugular and subclavian approaches are commonly used for conventional chest ports, although access-site selection should incorporate vascular anatomy, previous central venous procedures, thrombotic and bleeding risk, respiratory status, expected device position, and operator expertise. A 2025 meta-analysis of six randomized trials comparing internal jugular and subclavian venous access for implantable port placement in patients receiving cancer chemotherapy found lower rates of total complications, catheter misplacement, and port/catheter-related bloodstream infection with internal jugular access, although procedure duration was longer [38]. Thus, the route of implantation may influence clinical outcomes and should not be chosen on technical convenience alone.

Between infusions, the absence of external tubing may facilitate bathing, clothing, and activity. These benefits must be balanced against implantation, repeated needle access, and patient-specific procedural and infection risks [2,4,15,17].

Implantation carries risks of bleeding, arterial injury, pneumothorax with relevant thoracic routes, malposition, and pocket complications. Later events may include pocket infection, bloodstream infection, catheter-associated thrombosis, occlusion, migration, fracture, and device dysfunction [12,15,19,20]. Importantly, Qiu et al. reported more pocket or exit-site infections without septicemia and more pain among implantable-port recipients than among PICC recipients, despite port advantages for several other outcomes; the authors' outcome-specific findings should not be interpreted as a universal hierarchy [37].

The trade-off therefore depends on the indication and outcome of concern. In oncology, comparative evidence supports ports for selected complication endpoints, but chemotherapy urgency, treatment pattern, available veins, procedural risk, and acceptability of needle access may justify alternative devices [4,17,21,22,37].

3.5. Upper-Arm Ports and PICC-Port Systems

Upper-arm implantable ports place the reservoir in the arm rather than the chest. The term PICC port specifically denotes a totally implanted system introduced through a deep upper-arm vein using a PICC-like approach, with the catheter advanced to a central position. Not every arm port shares this construction. Precise terminology should reflect insertion route and device design [13,25].

A PICC port combines upper-arm venous entry with a buried reservoir. Avoiding direct thoracic venipuncture removes the associated needle-access risk of pneumothorax, while the absence of an external segment can reduce dressing and connector care compared with a conventional PICC. This may suit patients who need implanted access but have anatomical, treatment-related, or personal reasons to avoid a chest port. It does not remove the possibility of upper-extremity thrombosis or venous injury. Preprocedural assessment should address vein caliber and patency, catheter size, prior thrombosis, local surgery, lymphatic disruption, and treatment needs [3,13,17].

Evidence for PICC ports is growing but remains less mature than that for conventional PICCs and chest ports. Bertoglio et al. documented feasibility in patients receiving chemotherapy for breast cancer [14]. In a prospective observational study of 210 women undergoing neoadjuvant chemotherapy, Pinelli et al. reported better acceptance and some quality-of-life outcomes with PICC ports; infection, thrombosis, obstruction, and secondary malposition did not differ significantly [23]. Crucially, the treatment groups were sequential, nonrandomized cohorts, limiting causal inference and generalizability.

PICC-port studies differ in patient populations, insertion approaches, device designs, follow-up, and complication definitions. Direct randomized comparisons with chest ports remain scarce; technical consensus [13] therefore supplements rather than replaces comparative outcome evidence.

Upper-arm implantation may be appropriate when durable implanted access is desired, and arm-vein anatomy permits it. Evaluation should include vessel size, thrombosis and lymphatic risks, previous ipsilateral treatment, and patient priorities [13,17]. Prospective comparative studies should assess device survival, complications, cost, and validated patient-reported outcomes.

3.6. Femorally Inserted and Alternative Central Venous Access

Femorally inserted central catheters (FICCs) enter through the femoral venous system and terminate centrally in the inferior vena cava. Current terminology distinguishes them from CICCs on the basis of insertion route [25]. Elective FICC placement, often involving tunneling and a deliberately selected exit site, should also be distinguished from a short emergency femoral catheter placed at the groin.

Elective FICC placement may involve ultrasound-guided access, careful vessel-to-catheter sizing, tunneling to move the exit site away from the inguinal region, securement, and confirmation of tip position [27]. These techniques differ from conventional emergency femoral cannulation, but comparative evidence remains limited. Equivalent safety to established upper-body access routes should therefore not be assumed.

Because the device must function as a central line, its tip should lie at an appropriate location in the inferior vena cava. Ultrasound-based intraprocedural assessment is among the methods used to guide this process [27]. Accurate tip placement is especially important when lower-body access is chosen because upper-body pathways cannot be used.

FICCs may offer a useful route when upper-body access is unavailable, contraindicated, or best preserved. Potential scenarios include superior vena cava obstruction, extensive upper-body thrombosis or stenosis, exhausted upper-body venous anatomy, and selected circumstances in which preservation of remaining upper-extremity veins is important [3,27].

Emergency non-tunneled femoral access and elective tunneled FICC placement should not be considered interchangeable, as they differ in clinical indication, insertion setting, exit-site strategy, anticipated dwell time, and maintenance requirements. Before elective placement, consider mobility, body habitus, local skin condition, complication risks, likely duration, and ability to provide catheter care.

Oncology-specific data largely concern feasibility rather than comparative effectiveness. Parejo Arrondo et al. reported a series of 25 FICCs placed in oncology patients requiring elective central access in the absence of viable upper-body venous access. No catheter-related bloodstream infections or symptomatic catheter-related thromboses were reported in this small, highly selected cohort [39]. Given its retrospective design and small sample, this series cannot establish comparative safety or efficacy.

Severe central venous obstruction or exhaustion of conventional pathways may require nonstandard access. Such procedures are contingency options rather than routine substitutes for conventional CVADs and should be undertaken by experienced teams after multidisciplinary evaluation of vascular anatomy, procedural hazards, expected benefit, prognosis, and remaining venous capital [3,12].

Although contemporary FICC techniques expand access options, current outcome data derive mainly from small observational series. Comparative studies with standardized definitions of infection, thrombosis, device survival, and patient-reported outcomes are needed to define their place relative to upper-body devices [27,39].

Table 1 compares established and emerging configurations by access route, use pattern, benefits, and limitations; the entries do not constitute a ranking or a fixed dwell-time rule [2,4,12,16,17].

Table 1. Comparative characteristics and clinical applications of commonly used vascular access devices.

Device	Insertion and Access Pattern	Typical Clinical Context	Main Trade-Offs	References
Non-tunneled CICC	Direct central venipuncture; typically short-term	Urgent/critical care; central infusates; rapid or multiple infusions	Immediate central access; external maintenance, insertion and infection risks	[1,2,28,32]
PICC	Upper-arm vein to central tip; short to prolonged use as indicated	Intravenous antimicrobials, cancer therapy, parenteral nutrition	No thoracic puncture; arm-vein thrombosis and external-care burden	[1,3,20,26,37]
Tunneled CVC	Central insertion with subcutaneous tunnel; prolonged access	Frequent/continuous therapy, home parenteral nutrition, transplantation	Durable multi-access use; external exit site and infection risk	[25,33,35]
Chest implanted port (TIVAD)	Central catheter with subcutaneous reservoir; intermittent long-term access	Repeated or intermittent systemic cancer treatment	No external segment when idle; surgery and non-coring needle access required	[2,15,17,21,22,37]
Upper-arm port/PICC port	Upper-arm vein to central tip, implanted reservoir	Selected patients requiring totally implanted access	Fully implanted, no thoracic puncture; arm-vein risks and limited comparisons	[13,14,23,25]
FICC	Femoral insertion to central tip; tunneling when indicated	Selected patients with unsuitable upper-body access	Alternative route; infection, thrombosis and care implications must be assessed	[3,25,27,39]

Abbreviations: CICC, centrally inserted central catheter; FICC, femorally inserted central catheter; PICC, peripherally inserted central catheter; TIVAD, totally implantable venous access device. Note: Dwell time is indicative, not a fixed eligibility threshold. Weigh treatment needs, anatomy, risk, venous preservation, and preferences. Reference [40] is an ongoing trial without reported comparative outcomes.

3.7. Patient-Specific Risk Stratification and Device Matching

Device selection should integrate treatment characteristics with venous anatomy, prior access history, thrombosis and infection risk, renal function, potential future dialysis access, available insertion sites, maintenance capacity, and patient priorities. The aim is not to apply a single score indiscriminately but to identify modifiable risks and select the least burdensome clinically suitable access strategy [2–4,17].

For patients considered for a PICC, catheter-associated thrombosis warrants explicit assessment. The Michigan Risk Score was developed using data from 23,010 PICC recipients, of whom 475 (2.1%) experienced symptomatic PICC-associated deep-vein thrombosis; observed rates ranged from 0.9% to 4.7% across four risk classes [41]. It incorporates patient- and catheter-related predictors and may inform PICC-specific risk discussions, but its original evaluation does not establish universal applicability to other CVAD types or all clinical settings. The Khorana score addresses cancer-associated venous thromboembolism rather than PICC-associated thrombosis specifically and should not be treated as an interchangeable catheter-selection model. Insertion planning should also address the smallest practicable catheter diameter, minimum number of lumens, ultrasound-defined vein caliber, and catheter-to-vein relationship. A catheter-to-vein ratio above 45% has been associated with thrombosis in observational research [26]; it should be considered a risk signal rather than a universally validated absolute contraindication.

Preservation of venous capital is especially important in advanced chronic kidney disease and in patients who may require future hemodialysis. Where future arteriovenous access is a realistic possibility, nephrology consultation and multidisciplinary planning should precede upper-extremity catheter placement when clinically feasible [4,30,33]. Prior upper-extremity thrombosis, stenosis, surgery, or radiation may further limit access options. Finally, treatment frequency and access pattern should be evaluated separately from anticipated duration: intermittent long-term treatment may favor an implanted port when suitable, whereas frequent or continuous access can justify an external device depending on the complete clinical context [2,12,15–17].

Previous upper-extremity thrombosis, venous obstruction, surgery, irradiation, or limited peripheral vessels call for assessment of the intended access route before insertion. A PICC port or upper-arm port still uses upper-extremity veins and does not eliminate local thrombotic or stenotic risks. FICC placement may be considered if upper-body pathways are unsuitable, provided that anatomy, tip location, tunneling, maintenance, and potential complications are evaluated by an experienced team [13,27,39].

Infection exposure and the ability to maintain a device also influence its suitability. External catheters require consistent dressing, hub, connector, and securement care, sometimes with caregiver or nursing support. Ports can reduce this external burden between intermittent treatments but still require aseptic needle access and remain vulnerable to infection [2,12,15,17,32].

Where several devices are clinically reasonable, ask about needle access, body image, bathing, physical activity, visible tubing, and the demands of ongoing care. These expressed preferences should not be confused with outcomes measured using psychometrically validated patient-reported instruments. Observational PICC-port experience may inform such conversations without proving superiority over established options [13,14,23]. Table 2 provides an author-developed aid to clinical reasoning, not a validated score or treatment algorithm.

Table 2. Patient-specific risks and proposed implications for CVAD selection (author-developed, not validated).

Patient or Clinical Factor	Principal Concern	Implications for Individualized Device Selection	Key References
Acute hematologic cancer requiring urgent chemotherapy	Urgent delivery, complex therapy, multiple simultaneous infusions	MAGIC-ONC: a double-lumen PICC or tunneled CVC was rated appropriate. Confirm lumen need, duration, available veins and thrombosis risk; these are expert appropriateness ratings, not an exclusive rule.	[4]
Solid tumor requiring chemotherapy, including prolonged intermittent treatment	Treatment pattern, planned dwell time and maintenance burden	MAGIC-ONC: a single-lumen tunneled CVC or implanted port was rated appropriate regardless of treatment intensity, urgency or duration. Match selection to access pattern, treatment plan, anatomy and patient preferences.	[4]
Previous venous thromboembolism, malignancy-associated thrombosis, or other increased thrombotic risk	Catheter-related thrombosis and premature device failure	Assess venous anatomy and patency before insertion; use the smallest catheter caliber and minimum number of lumens compatible with therapy. Device type and insertion site should be individualized rather than selecting a PICC solely for procedural convenience.	[2,20,26]
Small upper-extremity veins or an unfavorable catheter-to-vein relationship	Reduced venous flow and increased risk of symptomatic PICC-related thrombosis	Use ultrasound to assess vessel diameter and select the smallest feasible catheter. A catheter-to-vein ratio > 45% has been associated with increased symptomatic thrombosis risk, but no single threshold should be used in isolation. Consider an alternative vessel, site, or device if venous occupancy is excessive.	[2,3,26]
Advanced chronic kidney disease or a meaningful likelihood of future hemodialysis	Loss of venous capital and potential compromise of future arteriovenous access	Avoid unnecessary upper-extremity PICC placement and preserve veins that may be required for future dialysis access. Multidisciplinary assessment is advisable when immediate treatment requirements compete with long-term vascular-access preservation.	[4,30,33]
Prolonged intermittent systemic anticancer therapy	Need for durable access with lower external maintenance burden	A totally implantable venous access device may be favored when anatomy and procedural risk are acceptable. Comparative oncology evidence generally favors ports over PICCs for several device-related outcomes, although this should not be interpreted as universal superiority.	[4,17,21,22,37]
Frequent or continuous central venous access	Repeated access requirements, infusion complexity, and practicality of long-term use	An external PICC or tunneled catheter may be appropriate depending on anticipated duration, required number of lumens, infusion characteristics, vascular anatomy, and the patient's ability to manage an external device. Treatment pattern should be considered separately from treatment duration.	[2,3,16,17,35]

Table 2. *Cont.*

Patient or Clinical Factor	Principal Concern	Implications for Individualized Device Selection	Key References
Previous thoracic or upper-extremity surgery, radiotherapy, lymph-node dissection, burns, or local tissue limitations	Altered anatomy, impaired tissue integrity, lymphatic considerations, or reduced feasibility of conventional access	Avoid a rigid site hierarchy. Individualized imaging and clinical assessment may support an upper-arm port or PICC port when fully implanted access is desirable and upper-arm anatomy is suitable, or another alternative access route when conventional thoracic placement is unsuitable.	[3,12,13,17,25]
Superior vena cava obstruction, extensive upper-body thrombosis or stenosis, or exhausted upper-body venous access	Absence of a suitable conventional upper-body access route	A contemporary FICC may be considered in carefully selected patients after assessment of lower-body venous anatomy, infection and thrombosis risk, mobility, expected dwell time, and capacity for device care. Current evidence supports feasibility but not equivalence or superiority to established upper-body devices.	[3,25,27,39]
High maintenance burden or limited ability to care for an external catheter	Dressing, hub-care, securement, contamination, and accidental dislodgement	When prolonged intermittent access is required, and implantation is clinically appropriate, a totally implanted system may reduce the burden associated with an external catheter. Device choice should also account for access frequency, caregiver support, follow-up resources, and local vascular-access expertise.	[2,12,15,17,32]
Strong body-image, lifestyle, bathing, occupational, or physical-activity concerns	Long-term acceptability and treatment burden	Incorporate patient preference through shared decision-making when more than one clinically appropriate option exists. A fully implanted port or PICC port may offer advantages for selected patients who prioritize reduced visibility and external maintenance, while acknowledging the need for implantation and needle access.	[17,23]
Previous catheter-related infection or increased infectious risk	Catheter-related bloodstream infection, pocket infection, or premature removal	Do not assume that one device category eliminates infection risk. Device choice should be integrated with insertion-site assessment, aseptic insertion, maintenance practices, hub and dressing care, access frequency, and prompt removal when the device is no longer indicated.	[2,12,19,28,31,32]

Note: The entries synthesize published evidence and appropriateness guidance into an author-proposed, nonvalidated clinical framework. Choices require consideration of treatment urgency and pattern, vascular anatomy, infection and thrombosis risk, vein preservation, local expertise, maintenance capacity and patient priorities; the table is not a prescriptive algorithm. Abbreviations: FICC, femorally inserted central catheter; PICC, peripherally inserted central catheter; CVC, central venous catheter; MAGIC-ONC, Michigan Appropriateness Guide for Intravenous Catheters in Adult Patients with Cancer.

4. Discussion and Future Perspectives

The relative merits of CVADs depend on the outcome examined: a device associated with fewer thrombotic events may differ in local infection, pain, or maintenance burden. Figure 1 and Table 2 bring these trade-offs together as author-proposed aids for shared discussion, not externally validated selection algorithms [4,17,21,22,37].

Appropriateness guidance helps translate these principles into specific scenarios. MAGIC-ONC judged a double-lumen PICC or tunneled CVC appropriate for urgent chemotherapy in acute hematologic malignancy; for solid tumors, a single-lumen tunneled catheter or implanted port was rated appropriate across several chemotherapy scenarios differing in treatment intensity, urgency, and duration [4]. These panel judgments are not equivalent to randomized comparisons. Catheter diameter, lumen count, vein size, tip position, insertion technique, and maintenance capacity still affect the risk–benefit assessment [2,3,9,10,26].

Upper-arm implanted systems avoid direct thoracic venipuncture but depend on suitable arm veins. A meta-analysis of 13 comparative studies including 3896 patients found no clear difference between arm and chest ports in overall complications, infection, or thrombosis, although technical conversion was more frequent with arm ports [42]. A synthesis focused on breast cancer suggested a higher thrombosis risk with arm ports [43]. Population and device differences, together with the predominantly observational evidence, limit extrapolation to PICC-port systems. PICCHEST was an ongoing trial in the cited registration and should not be described as providing comparative results [40].

When upper-body pathways are unsuitable, femoral or other alternative routes merit specialist assessment of venous anatomy, maintenance demands, and complications [27,39].

Infection-prevention technologies differ substantially in the strength of supporting evidence. A Cochrane review including 57 trials and 16,784 catheters found that antiseptic- or antibiotic-impregnated central venous catheters reduced catheter-related bloodstream infection (RR 0.62, 95% CI 0.52–0.74) but did not demonstrate reductions in clinically diagnosed sepsis or all-cause mortality [44]. Much of the evidence concerns short-term inpatient access and does not establish routine benefit for long-term oncology catheters or home parenteral nutrition. Impregnated devices may complement, but cannot replace, established insertion and maintenance bundles [32]. By contrast, multifunctional antifouling, antimicrobial, and antithrombogenic experimental surfaces require clinical outcome validation before routine adoption [45,46].

Emerging machine-learning thrombosis prediction models require external validation, calibration, and prospective impact assessment, while sensor-based monitoring remains developmental [47–49]. These technologies should not replace clinical assessment or established catheter-specific risk evaluation.

Future multicenter comparisons should use standardized complication definitions and exposure denominators, report device survival and costs over the treatment pathway, and incorporate validated patient-reported measures distinct from preferences expressed in consultation [18–20,23,50].

5. Conclusions

Clinical selection of CVADs should begin with infusion requirements and access pattern, then account for vascular anatomy, thrombosis and infection risk, long-term vein preservation, procedural feasibility, and the patient's capacity to manage the device [2–4,17]. Early nephrology involvement is important when future hemodialysis access is a realistic prospect [4,30,33].

Upper-arm ports, PICC ports, and FICCs extend the available pathways, but their comparative evidence remains limited [13,14,23,27,39]. Established antimicrobial impreg-

nation has demonstrated benefits for selected infection outcomes, whereas experimental surfaces, prediction models, and monitoring sensors require further evaluation [32,44–49]. Future research should prioritize prospective head-to-head comparisons, catheter-specific risk validation, and standardized patient-reported outcomes.

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Abbreviations

The following abbreviations are used in this manuscript:

CICC	Centrally inserted central catheter
CRBSI	Catheter-related bloodstream infection
CVAD	Central venous access device
FICC	Femorally inserted central catheter
nT-CICC	Non-tunneled centrally inserted central catheter
PICC	Peripherally inserted central catheter
T-CVC	Tunneled central venous catheter
TIVAD	Totally implantable venous access device

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